CLAIMS:

1. A panoramic photographic apparatus comprising:

a mirror; and

means for mounting the mirror on an axis;

wherein the mirror includes a convex reflective surface symmetric about the axis, the surface forming a first angle C with respect to a first plane perpendicular to the axis at a point of intersection between the axis and the mirror, the first angle C being determined by a lower limit of a controlled vertical field of view.

2. A panoramic photographic apparatus according to Claim 1, wherein the first angle C ranges from about 0.5° to about 20°.

3. A panoramic photographic apparatus according to Claim 1, wherein the first angle C ranges from about 1° to about 10°.

4. A panoramic photographic apparatus according to Claim 1, wherein the first angle C ranges from about 2° to about 8°.

5. A panoramic photographic apparatus according to Claim 1, wherein the first angle C is about 5°.

6. A panoramic photographic apparatus according to Claim 1, wherein the surface further forms a second angle D with respect to a second plane perpendicular to the axis at an end of the mirror opposite the point of intersection between the axis and the mirror, the second angle D being determined by an upper limit of a controlled vertical field of view and a lower limit of a controlled vertical field of view.

7. A panoramic photographic apparatus according to Claim 6, wherein the second angle D ranges from about 50° to about 100°.

8. A panoramic photographic apparatus according to Claim 1, wherein the convex reflective surface comprises a surface of rotation defined by rotating around the axis: an equi-angular shape, a compensated equi-angular shape, a parabolic shape, a hyperbolic shape, or a spherical shape.

9. A panoramic photographic apparatus according to Claim 8, wherein the mirror has a compensated equi-angular shape described by the equation:

$$\frac{dr}{d\left(\theta+\frac{A}{\alpha}\right)} = r\cot\left(k\tan\left(\theta+\frac{A}{\alpha}\right)+\frac{\pi}{2}\right)$$

where θ is the angle that a light ray makes with the axis as it reflects off of a point on the surface of the mirror and into a camera lens, r is the length of a light ray between the camera lens and a point on the surface of the mirror, α is a constant defining the gain, and k is a constant defined by $(-1 - \alpha)/2$.

10. A panoramic photographic apparatus according to Claim 9, wherein α ranges from about 3 to about 15.

11. A panoramic photographic apparatus according to Claim 1, wherein the means for mounting the mirror on an axis comprises:

a cylinder;

wherein a first end of the cylinder is attached to a lens of a camera and wherein the mirror is mounted at a second end of the cylinder.

12. A panoramic photographic apparatus comprising:

a rod positioned on an axis; and

a mirror mounted at a first end of the rod;

wherein the mirror includes a convex reflective surface symmetric about the axis, the surface forming a first angle E with respect to a first plane perpendicular to the axis at a point of intersection between the rod and the mirror, the first angle E being determined by a lower limit of a controlled vertical field of view.

13. A panoramic photographic apparatus according to Claim 12, wherein the first angle E ranges from about 5° to about 30°.

14. A panoramic photographic apparatus according to Claim 12, wherein the first angle E ranges from about 10° to about 20°.

15. A panoramic photographic apparatus according to Claim 12, wherein the first angle E ranges from about 12° to about 16°.

16. A panoramic photographic apparatus according to Claim 12, wherein the first angle E is about 14°.

17. A panoramic photographic apparatus according to Claim 12, wherein the surface further forms a second angle D with respect to a second plane perpendicular to the axis at an end of the mirror opposite the point of intersection between the rod and the mirror,

the second angle D being determined by an upper limit of a controlled vertical field of view and a lower limit of a controlled vertical field of view.

18. A panoramic photographic apparatus according to Claim 17, wherein the second angle D ranges from about 50° to about 100°.

19. A panoramic photographic apparatus according to Claim 12, wherein the convex reflective surface comprises a surface of rotation defined by rotating around the axis: an equi-angular shape, a compensated equi-angular shape, a parabolic shape, a hyperbolic shape, or a spherical shape.

20. A panoramic photographic apparatus according to Claim 19, wherein the mirror has a compensated equi-angular shape described by the equation:

$$\frac{dr}{d\left(\theta + \frac{A}{\alpha}\right)} = r\cot\left(k\tan\left(\theta + \frac{A}{\alpha}\right) + \frac{\pi}{2}\right)$$

where θ is the angle that a light ray makes with the axis as it reflects off of a point on the surface of the mirror and into a camera lens, r is the length of a light ray between the camera lens and a point on the surface of the mirror, α is a constant defining the gain, and k is a constant defined by $(-1 - \alpha)/2$.

21. A panoramic photographic apparatus according to Claim 20, wherein α ranges from about 3 to about 15.

22. A panoramic photographic apparatus according to Claim 12, wherein the mirror is supported by the rod.

23. A panoramic photographic apparatus according to Claim 12, wherein the rod reduces unwanted reflections in the mirror.

24. A panoramic photographic apparatus according to Claim 12, wherein the rod is substantially cylindrical in shape.

25. A system for providing enhanced panoramic images comprising:

a mirror;

means for mounting the mirror on an axis;

wherein the mirror includes a convex reflective surface symmetric about the axis, the surface forming a first angle C with respect to a first plane perpendicular to the axis at a point of intersection between the axis and the mirror, the first angle C being determined by a lower limit of a controlled vertical field of view; and

a camera with a lens;

wherein the camera is positioned so that the lens is substantially aligned with the axis.

26. A system for providing enhanced panoramic images according to Claim 25, wherein the first angle C ranges from about 0.5° to about 20°.

27. A system for providing enhanced panoramic images according to Claim 25, wherein the surface further forms a second angle D with respect to a second plane perpendicular to the axis at an end of the mirror opposite the point of intersection between the axis and the mirror, the second angle D being determined by upper limit of a controlled vertical field of view and a lower limit of a controlled vertical field of view.

28. A system for providing enhanced panoramic images according to Claim 27, wherein the second angle D ranges from about 50° to about 100°.

29. A system for providing enhanced panoramic images according to Claim 25, wherein the convex reflective surface comprises a surface of rotation defined by rotating around the axis: an equi-angular shape, a compensated equi-angular shape, a parabolic shape, a hyperbolic shape, or a spherical shape.

30. A system for providing enhanced panoramic images according to Claim 29, wherein the mirror has a compensated equi-angular shape described by the equation:

$$\frac{dr}{d\left(\theta + \frac{A}{\alpha}\right)} = r\cot\left(k\tan\left(\theta + \frac{A}{\alpha}\right) + \frac{\pi}{2}\right)$$

where θ is the angle that a light ray makes with the axis as it reflects off of a point on the surface of the mirror and into a camera lens, r is the length of a light ray between the camera lens and a point on the surface of the mirror, α is a constant defining the gain, and k is a constant defined by (-1 - α)/2.

31. A system for providing enhanced panoramic images according to Claim 25, wherein the means for mounting the mirror on the axis comprises:

a cylinder;

wherein a first end of the cylinder is attached to the lens of the camera and wherein the mirror is mounted at a second end of the cylinder.

32. A system for providing enhanced panoramic images according to Claim 31, wherein the cylinder has a length of from about 3 cm to about 12 cm.

33. A system for providing enhanced panoramic images according to Claim 31, wherein the mirror has a diameter of from about 0.3 cm to about 60 cm.

34. A system for providing enhanced panoramic images according to Claim 25, wherein the system produces a high-resolution viewable panoramic image.

35. A system for providing enhanced panoramic images according to Claim 25, wherein the system further comprises an additional mirror positioned adjacent the mirror and an additional camera positioned for cooperation with the additional mirror.

36. A system for providing enhanced panoramic images comprising:

a mirror;

a rod positioned on an axis;

means for mounting the mirror on the axis;

wherein the mirror includes a convex reflective surface symmetric about the axis, the surface forming a first angle E with respect to a first plane perpendicular to the axis at a point of intersection between the rod and the mirror, the first angle E being determined by a lower limit of a controlled vertical field of view; and

a camera with a lens;

wherein the camera is positioned so that the lens is substantially aligned with the axis.

37. A system for providing enhanced panoramic images according to Claim 36, wherein the first angle E ranges from about 5° to about 30°.

38. A system for providing enhanced panoramic images according to Claim 36, wherein the surface further forms a second angle D with respect to a second plane perpendicular to the axis at an end of the mirror opposite the point of intersection between the rod and the mirror, the second angle D being determined by upper limit of a controlled vertical field of view and a lower limit of a controlled vertical field of view.

39. A system for providing enhanced panoramic images according to Claim 38, wherein the second angle D ranges from about 50° to about 100°.

40. A system for providing enhanced panoramic images according to Claim 36, wherein the convex reflective surface comprises a surface of rotation defined by rotating around the axis: an equi-angular shape, a compensated equi-angular shape, a parabolic shape, a hyperbolic shape, or a spherical shape.

41. A system for providing enhanced panoramic images according to Claim 40, wherein the mirror has a compensated equi-angular shape described by the equation:

$$\frac{dr}{d\left(\theta + \frac{A}{\alpha}\right)} = r\cot\left(k\tan\left(\theta + \frac{A}{\alpha}\right) + \frac{\pi}{2}\right)$$

where θ is the angle that a light ray makes with the axis as it reflects off of a point on the surface of the mirror and into a camera lens, r is the length of a light ray between the camera lens and a point on the surface of the mirror, α is a constant defining the gain, and k is a constant defined by $(-1 - \alpha)/2$.

42. A system for providing enhanced panoramic images according to Claim 36, wherein the means for mounting the mirror on the axis comprises the rod and the mirror is mounted at a first end of the rod and a second end of the rod is attached to the camera.

43. A system for providing enhanced panoramic images according to Claim 42, wherein the rod has a length of from about 3 cm to about 12 cm.

44. A system for providing enhanced panoramic images according to Claim 42, wherein the rod has a diameter of from about .05 cm to about 15 cm.

45. A system for providing enhanced panoramic images according to Claim 42, wherein the mirror has a diameter of from about 0.3 cm to about 60 cm.

46. A system for providing enhanced panoramic images according to Claim 42, wherein the mounting rod has a diameter D_R, the mirror has a diameter D_M, and the ratio of D_R:D_M is greater than 1:4.

47. A system for providing enhanced panoramic images according to Claim 36, wherein the means for mounting the mirror on the axis comprises:

a primary stage,

wherein the primary stage is attached to a camera; and

a secondary stage,

wherein the secondary stage is affixed to the primary stage.

48. A system for providing enhanced panoramic images according to Claim 47, wherein the secondary stage comprises:

the rod;

wherein the mirror is mounted at a first end of the rod and a second end of the rod is attached to the primary stage.

49. A system for providing enhanced panoramic images according to Claim 47, wherein the primary stage has a length of from about 1 cm to about 8 cm.

50. A system for providing enhanced panoramic images according to Claim 48, wherein the rod has a length of from about 2 cm to about 6 cm.

51. A system for providing enhanced panoramic images according to Claim 48, wherein the rod has a diameter of from about .05 cm to about 15 cm.

52. A system for providing enhanced panoramic images according to Claim 47, wherein the mirror has a diameter of from about 0.3 cm to about 60 cm.

53. A system for providing enhanced panoramic images according to Claim 48, wherein the rod has a diameter D_R, the mirror has a diameter D_M, and the ratio of D_R:D_M is greater than 1:4.

54. A system for providing enhanced panoramic images according to Claim 36, wherein the means for mounting the mirror on the axis comprises:

a cylinder;

wherein a first end of the cylinder is attached to the lens of the camera and wherein the mirror is mounted at a second end of the cylinder.

55. A system for providing enhanced panoramic images according to Claim 54, wherein the cylinder has a length of from about 3 cm to about 12 cm.

56. A system for providing enhanced panoramic images according to Claim 54, wherein the mirror has a diameter of from about 0.3 cm to about 60 cm.

57. A system for providing enhanced panoramic images according to Claim 36, wherein the system produces a high-resolution viewable panoramic image.

58. A system for providing enhanced panoramic images according to Claim 25, wherein the system further comprises an additional mirror positioned adjacent the mirror and an additional camera positioned for cooperation with the additional mirror.

59. A method of providing enhanced panoramic images comprising optimizing a resolution of a mirror, wherein the resolution is optimized by selecting the resolution based upon controlling at least one parameter selected from: a shape of the mirror, an upper limit of a controlled vertical field of view, a lower limit of a controlled vertical field of view, an upper limit of a desired vertical field of view, a lower limit of a desired vertical field of view, and a vertical pixel radius.

60. A method according to Claim 59, wherein the resolution is selected based upon controlling at least two of the parameters.

61. A method according to Claim 59, wherein the resolution is selected based upon controlling at least three of the parameters.

62. A method according to Claim 59, wherein the resolution is selected based upon controlling at least four of the parameters.

63. A method according to Claim 59, wherein the resolution is selected based upon controlling at least five of the parameters.

64. A method according to Claim 59, wherein the resolution is selected based upon controlling at least six of the parameters.

65. A method according to Claim 59, wherein at least one parameter for selecting the resolution is the shape of the mirror.

66. A method according to Claim 59, wherein at least one parameter for selecting the resolution is the upper limit of the controlled vertical field of view.

67. A method according to Claim 59, wherein at least one parameter for selecting the resolution is the lower limit of the controlled vertical field of view.

68. A method according to Claim 59, wherein at least one parameter for selecting the resolution is the upper limit of the desired vertical field of view.

69. A method according to Claim 59, wherein at least one parameter for selecting the resolution is the lower limit of the desired vertical field of view.

70. A method according to Claim 59, wherein at least one parameter for selecting the resolution is the vertical pixel radius.

71. A method according to Claim 59, wherein the resolution comprises a horizontal resolution at the upper limit of the desired vertical field of view, a horizontal resolution at the lower limit of the desired vertical field of view, and a vertical resolution.

72. A method according to Claim 71, wherein the horizontal resolution at the upper limit of the desired vertical field of view is substantially determined by the equation:

$$HR_{upper} = \frac{2\pi VP_r}{360°}$$

where VP_r is the vertical pixel radius between the lower limit of the controlled vertical field of view and the upper limit of the controlled vertical field of view.

73. A method according to Claim 71, wherein the horizontal resolution at the lower limit of the desired vertical field of view is substantially determined by the equation:

$$HR_{lower} = \frac{\left(\frac{A'-A}{B-A}\right)(2\pi VP_r)}{360°}$$

where A' is the lower limit of the desired vertical field of view, A is the lower limit of the controlled vertical field of view, B is the upper limit of the controlled vertical field of view, and VP_r is the vertical pixel radius between the lower limit of the controlled vertical field of view and the upper limit of the controlled vertical field of view.

74. A method according to Claim 71, wherein the vertical resolution is substantially determined by the equation:

$$VR = \frac{VP_r}{(B-A)}$$

where A is the lower limit of the controlled vertical field of view, B is the upper limit of the controlled vertical field of view, and VP_r is the vertical pixel radius between the lower limit of the controlled vertical field of view and the upper limit of the controlled vertical field of view.

75. A method according to Claim 59 further comprising evaluating the pixel size of a viewable panoramic image within the desired vertical field of view.

76. A method according to Claim 59 further comprising ensuring that portions of a viewable panoramic image within the desired vertical field of view are not obscured an image of a camera by selecting a first distance the mirror is placed from the camera based upon controlling at least one parameter selected from: a second distance the furthest edge of the camera is from the axis of the camera, and the lower limit of the desired vertical field of view.

77. A method according to Claim 76, wherein the first distance the mirror is placed from the camera is selected based upon controlling at least one of the parameters.

78. A method according to Claim 76, wherein the first distance the mirror is placed from the camera is selected based upon controlling at least two of the parameters.

79. A method according to Claim 76, wherein at least one parameter for selecting the first distance the mirror is placed from the camera is the second distance the furthest edge of the camera is from the axis of the camera.

80. A method according to Claim 76, wherein at least one parameter for selecting the first distance the mirror is placed from the camera is the lower limit of the desired vertical field of view.

81. A method according to Claim 59 further comprising ensuring that portions of the viewable panoramic image within the desired vertical field of view are not obscured an image of a mirror mount by selecting a third distance the mirror is placed from a widest portion of the mirror mount based upon controlling at least one parameter selected from: a fourth distance the furthest edge of the widest portion of the mirror mount is from the axis of the camera, and the lower limit of the desired vertical field of view.

82. A method according to Claim 81, wherein the third distance the mirror is placed from a widest portion of the mirror mount is selected based upon controlling at least one of the parameters.

83. A method according to Claim 81, wherein the third distance the mirror is placed from a widest portion of the mirror mount is selected based upon controlling at least two of the parameters.

84. A method according to Claim 81, wherein at least one parameter for selecting the third distance the mirror is placed from a widest portion of the mirror mount is the fourth distance the furthest edge of the widest portion of the mirror mount is from the axis of the camera

85. A method according to Claim 81, wherein at least one parameter for selecting the third distance the mirror is placed from a widest portion of the mirror mount is the lower limit of the desired vertical field of view.

86. A method according to Claim 59 further comprising:

ensuring that portions of the viewable panoramic image within the desired vertical field of view are not obscured an image of a camera by selecting a first distance the mirror is placed from the camera based upon controlling at least one parameter selected from: a second distance the furthest edge of the camera is from the axis of the camera, and the lower limit of the desired vertical field of view; and

ensuring that portions of the viewable panoramic image within the desired vertical field of view are not obscured an image of a mirror mount by selecting a third distance the mirror is placed from a widest portion of the mirror mount based upon

controlling at least one parameter selected from: a fourth distance the furthest edge of the widest portion of the mirror mount is from the axis of the camera, and the lower limit of the desired vertical field of view.

87. A method according to Claim 59 further comprising:

mounting the mirror on the axis;

capturing a raw panoramic image; and

producing a viewable panoramic image.

88. A method according to Claim 87 further comprising cropping the viewable panoramic image to remove unwanted portions of the viewable panoramic image.

89. A method according to Claim 88, wherein a top portion of about an additional 0° to a top portion of about an additional 10° is cropped from the viewable panoramic image.

90. A method according to Claim 88, wherein a bottom portion of about an additional 0° to a bottom portion of about an additional 40° is cropped from the viewable panoramic image.

91. A method of providing enhanced panoramic images comprising:

providing a camera with a mirror, wherein the mirror includes a convex reflective surface symmetric about an axis;

obtaining a raw panoramic image using the camera and the mirror, the image having pixel representations comprising a vertical pixel radius, a horizontal pixel circumference at an upper limit of a desired vertical field of view, and a horizontal pixel circumference at a lower limit of a desired vertical field of view; and

optimizing a resolution of the mirror by modifying the mirror to obtain desired pixel representations.

92. A method according to Claim 91, wherein the raw panoramic image is a raw 360° image.

93. A method according to Claim 91, wherein the convex reflective surface forms a first angle C with respect to a first plane perpendicular to the axis at a point of intersection between the axis and the mirror, wherein the first angle C is determined by a lower limit of a controlled vertical field of view, and wherein the first angle C ranges from about 0.5° to about 20°.

94. A method according to Claim 91, wherein the convex reflective surface forms a second angle D with respect to a second plane perpendicular to the axis at an end of the mirror opposite the point of intersection between the axis and the mirror, wherein

the second angle D is determined by an upper limit of a controlled vertical field of view and a lower limit of a controlled vertical field of view, and wherein the second angle D ranges from about 50° to about 100°.

95. A method according to Claim 91, wherein the mirror is mounted at a first end of a rod, and wherein the rod is positioned on the axis.

96. A method according to Claim 95, wherein the convex reflective surface forms a third angle E with respect to a first plane perpendicular to the axis at a point of intersection between the rod and the mirror, wherein the third angle E is determined by a lower limit of a controlled vertical field of view, and wherein the third angle E ranges from about 5° to about 30°.